

CBSE Class 12 Biology Question Paper 2024 with Solution PDF-Set 57-S-3 - Compartment



Question Paper with Solutions

Conducted by the Central Board of Secondary Education (CBSE)

Time Allowed: 3 hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33** questions. All questions are **compulsory**.
- (ii) Question paper is divided into five sections – Sections **A, B, C, D** and **E**.
- (iii) **Section A** – questions number **1** to **16** are multiple choice type questions. Each question carries **1** mark.
- (iv) **Section B** – questions number **17** to **21** are very short answer type questions. Each question carries **2** marks.
- (v) **Section C** – questions number **22** to **28** are short answer type questions. Each question carries **3** marks.
- (vi) **Section D** – questions number **29** and **30** are case-based questions. Each question carries **4** marks. Each question has subparts with internal choice in one of the subparts.
- (vii) **Section E** – questions number **31** to **33** are long answer type questions. Each question carries **5** marks.
- (viii) There is no overall choice. However, an internal choice has been provided in Sections B, C and D of the question paper. A candidate has to write answer for only **one** of the alternatives in such questions.
- (ix) Kindly note that there is a separate question paper for Visually Impaired candidates.
- (x) Wherever necessary, neat and properly labelled diagrams should be drawn.

Section A (16 marks)

Questions no. 1 to 16 are Multiple Choice Type Questions, carrying 1 mark each. $16 \times 1 = 16$

1. The mosquito-borne disease in humans causing chronic inflammation of the lymphatic vessels is : [1 mark]

- (A) Elephantiasis
- (B) Ascariasis
- (C) Ringworm
- (D) Amoebiasis

Correct Answer: (A) Elephantiasis

Solution:

Concept:

- Lymphatic filariasis is caused by filarial worms such as *Wuchereria bancrofti*.
- Female mosquitoes transmit the parasite, which affects lymphatic vessels.

Step 1: Identify the defining symptoms Chronic inflammation of lymphatic vessels, accompanied by obstruction of lymph flow and swelling of body parts, is characteristic of lymphatic filariasis, commonly called elephantiasis. The mosquito-borne transmission in the question supports this identification.

Step 2: Eliminate the other diseases Ascariasis is an intestinal roundworm infection spread by ingestion of eggs. Ringworm is a fungal skin infection. Amoebiasis is an intestinal protozoan infection spread through contaminated food or water. None matches both mosquito transmission and lymphatic inflammation.

Step 3: Conclusion Elephantiasis is the required disease. Hence, the correct option is (A).

Quick Tip to Solve: Link mosquito transmission plus lymphatic blockage directly with elephantiasis.

2. In plants, which one of the following helps in the absorption of phosphorus from soil ? [1 mark]

- (A) *Glomus*
- (B) *Rhizobium*
- (C) *Frankia*
- (D) *Anabaena*

Correct Answer: (A) *Glomus*

Solution:

Concept:

- Mycorrhiza is a mutual association between a fungus and the roots of a plant.
- Fungal hyphae increase the effective absorbing surface and help the plant obtain phosphorus.

Step 1: Identify the phosphorus-absorbing partner *Glomus* is a mycorrhizal fungus. Its hyphae spread into the soil and absorb phosphorus, transferring this nutrient to the associated plant. The fungus receives organic nutrients from the plant in return.

Step 2: Compare the remaining organisms *Rhizobium* forms nitrogen-fixing nodules in legume roots, while *Frankia* fixes nitrogen in certain non-leguminous plants. *Anabaena* is a nitrogen-fixing cyanobacterium. Their standard biofertiliser role concerns nitrogen rather than the mycorrhizal absorption of phosphorus asked here.

Step 3: Conclusion *Glomus* helps plants absorb phosphorus from soil. Hence, the correct option is (A).

Quick Tip to Solve: For phosphorus uptake, recall mycorrhiza and *Glomus*; for nitrogen, recall nitrogen fixers.

3. Long ribbon-like pollen grains are seen in some :

[1 mark]

- (A) Aquatic plants
- (B) Wind-pollinated grasses
- (C) Gymnosperms
- (D) Bird-pollinated flowers

Correct Answer: (A) Aquatic plants

Solution:

Concept:

- Hydrophily is pollination through water and occurs in some aquatic plants.
- In some submerged plants, pollen shape helps transport and contact with the stigma.

Step 1: Relate pollen shape to water pollination In seagrasses such as *Zostera*, pollen grains are long and ribbon-like. They are carried passively by water currents and can reach and contact the submerged stigma. Thus, this pollen adaptation occurs in some aquatic plants.

Step 2: Assess the other groups Wind-pollinated grasses generally produce abundant, light pollen rather than the characteristic long ribbons. Gymnosperms are not identified by ribbon-like pollen; some have winged pollen. Bird-pollinated flowers generally have sticky pollen transferred by birds. Also, not every aquatic plant is water-pollinated: the question correctly says some.

Step 3: Conclusion Long ribbon-like pollen grains occur in some aquatic plants. Hence, the correct option is (A).

Quick Tip to Solve: Remember *Zostera* as the example linking ribbon-like pollen with underwater pollination.

4. Estrogen is secreted by :

[1 mark]

- (A) Corpus luteum
- (B) Membrane granulosa of Graafian follicle
- (C) Pituitary gland
- (D) Germinal epithelium

Correct Answer: (B) Membrane granulosa of Graafian follicle

Solution:

Concept:

- Growing ovarian follicles secrete estrogens, which support endometrial growth.
- The corpus luteum is principally associated with progesterone secretion after ovulation.

Step 1: Identify the follicular source The membrane granulosa, formed by granulosa cells of the Graafian follicle, is the expected source of estrogen among the listed choices. Follicular estrogen supports proliferation of the uterine endometrium during the follicular phase.

Step 2: Distinguish the other structures The pituitary secretes gonadotropins such as FSH and LH, which regulate ovarian activity; it is not the ovarian estrogen-secreting tissue. The ovarian germinal epithelium is not the specified endocrine source. Although the corpus luteum can also produce some estrogen, its principal hormone in this syllabus is progesterone, whereas the direct follicular source named here is membrane granulosa.

Step 3: Conclusion Estrogen is secreted by the membrane granulosa of the Graafian follicle. Hence, the correct option is (B).

Quick Tip to Solve: Associate the growing Graafian follicle with estrogen and the corpus luteum mainly with progesterone.

5. Crystals of Bt toxin produced by some bacteria, do not kill the bacteria producing them because :

[1 mark]

- (A) bacteria are resistant to the toxin
- (B) toxin is immature
- (C) toxin is inactive
- (D) bacteria encloses 'toxin' in a special capsule

Correct Answer: (C) toxin is inactive

Solution:

Concept:

- *Bacillus thuringiensis* produces insecticidal protein in an inactive protoxin form.
- Activation occurs in the alkaline gut of a susceptible insect, allowing damage to midgut epithelial cells.

Step 1: Explain safety within the bacterium The Bt protein crystals contain an inactive protoxin. In this form, the protein does not exert its insecticidal action on the bacterium that produces it. Thus, inactivity, rather than a special protective capsule, explains the observation.

Step 2: Identify activation and reject alternatives When a susceptible insect ingests the crystals, the alkaline gut environment solubilises them and the protoxin is activated. The active toxin binds to midgut epithelial cells and forms pores, causing cell damage. The printed choice inactive states this mechanism precisely. Immature is not the biological explanation, bacterial resistance is not the stated mechanism, and enclosure in a special capsule is incorrect.

Step 3: Conclusion The toxin is inactive in the producing bacterium. Hence, the correct option is (C).

Quick Tip to Solve: Recall the sequence: inactive protoxin in Bt, activation in the alkaline insect gut.

6. The population interaction where one species is harmed and the other is unaffected is : [1 mark]

- (A) Amensalism
- (B) Commensalism
- (C) Parasitism
- (D) Predation

Correct Answer: (A) Amensalism

Solution:

Concept:

- Population interactions are classified by their effects on each interacting species.
- Amensalism has effects $(-, 0)$: one species is harmed and the other is unaffected.

Step 1: Match the stated effects The question specifies harm to one population and no effect on the other. This is the defining relationship of amensalism, represented by $(-, 0)$. For example, a substance released by one organism may inhibit another without affecting the producer.

Step 2: Compare the alternative interactions Commensalism has effects $(+, 0)$, because one species benefits while the other is unaffected. Parasitism has effects $(+, -)$, with the parasite benefiting at the host's expense. Predation also has effects $(+, -)$, with the predator benefiting and the prey being harmed. Neither matches the stated absence of a benefit.

Step 3: Conclusion The interaction is amensalism. Hence, the correct option is (A).

Quick Tip to Solve: Write the effect pair first: harm plus no effect is $(-, 0)$, the signature of amensalism.

7. The most primitive ancestor of humans is :

[1 mark]

- (A) *Homo habilis*
- (B) *Australopithecus*
- (C) *Ramapithecus*
- (D) *Homo neanderthalensis*

Correct Answer: (C) *Ramapithecus*

Solution:

Concept:

- The textbook sequence of human evolution includes early primate forms followed by australopithecines and species of *Homo*.
- Among the listed forms, *Ramapithecus* belongs to the earliest stage in the conventional textbook account.

Step 1: Compare the evolutionary stages In the CBSE textbook account, *Ramapithecus* is described as more man-like than *Dryopithecus* and is placed much earlier than australopithecines and species of *Homo*. It is therefore the most primitive form among the four printed alternatives.

Step 2: Eliminate later forms *Australopithecus* represents a later australopithecine stage. *Homo habilis* is an early member of the genus *Homo*, while *Homo neanderthalensis* is a much later human form. Thus, neither of these later stages precedes *Ramapithecus* in the conventional sequence being tested.

Step 3: Conclusion Among the listed choices, the most primitive ancestor in the textbook account is *Ramapithecus*. Hence, the correct option is (C).

Quick Tip to Solve: Compare the listed stages chronologically: *Ramapithecus* precedes *Australopithecus* and *Homo* in this textbook sequence.

8. The sequence that controls the copy number of linked DNA in the vector is termed :

[1 mark]

- (A) Selectable marker
- (B) Ori site
- (C) Palindromic sequence
- (D) Recognition site

Correct Answer: (B) Ori site

Solution:

Concept:

- A cloning vector carries an origin of replication, usually called ori, from which DNA replication begins.
- The ori sequence also controls the number of copies of the vector and any DNA linked to it within the host cell.

Step 1: Identify the replication-control sequence DNA inserted into a vector replicates along with that vector in the host. Its copy number therefore depends on the replication properties specified by

the origin of replication (ori).

Step 2: Eliminate the other vector features A selectable marker identifies transformed cells; it does not control the number of DNA copies. Palindromic sequences and recognition sites provide sites for restriction-enzyme action and are used in DNA cutting and insertion.

Step 3: Conclusion The ori site controls the copy number of linked DNA. Hence, the correct option is (B).

Quick Tip to Solve: For a vector question, associate ori with replication and copy number, and a selectable marker with identifying transformants.

9. Which one of the following codons has dual function ?

[1 mark]

- (A) AUG
- (B) AUC
- (C) ACU
- (D) ACA

Correct Answer: (A) AUG

Solution:

Concept:

- A codon is a triplet of nucleotides in mRNA that specifies an amino acid or a translation signal.
- AUG specifies methionine and also serves as the initiation codon during translation.

Step 1: Identify the two functions AUG codes for the amino acid methionine when read during protein synthesis. At the start of the coding region it also signals initiation of translation, establishing the reading frame.

Step 2: Check the remaining codons AUC specifies isoleucine, whereas ACU and ACA specify threonine. These codons have amino-acid coding roles but do not have the standard initiation function asked for here.

Step 3: Conclusion AUG has the dual role of coding for methionine and initiating translation. Hence, the correct option is (A).

Quick Tip to Solve: Remember AUG as both the start signal for translation and the codon for methionine.

10. Which one of the following options gives the correct temperature condition and the mixture of the gaseous components that were used by S.L. Miller in 1953 to prove abiogenesis of life ? [1 mark]

- (A) CH_4 , H_2 , NO_2 and water vapour at 1800°C
- (B) CH_4 , H_2 , NH_3 and water vapour at 1800°C
- (C) CO_2 , H_2 , NH_3 and water vapour at 800°C
- (D) CH_4 , H_2 , NH_3 and water vapour at 800°C

Correct Answer: (D) CH_4 , H_2 , NH_3 and water vapour at 800°C

Solution:

Concept:

- The Miller experiment simulated reducing conditions proposed for the primitive atmosphere.
- Methane, hydrogen, ammonia and water vapour were exposed to electric discharge, leading to formation of organic compounds such as amino acids.

Step 1: Recall the experimental conditions The standard textbook description uses a mixture of CH_4 , H_2 , NH_3 and water vapour at 800°C , with electric discharge simulating lightning. Formation of amino acids supported chemical evolution.

Step 2: Compare all combinations Option (A) incorrectly includes NO_2 and gives 1800°C . Option (B) has the correct gases but the wrong temperature. Option (C) substitutes CO_2 for methane. Only (D) matches both the mixture and the stated temperature.

Step 3: Conclusion The required combination is CH_4 , H_2 , NH_3 and water vapour at 800°C . Hence, the correct option is (D).

Quick Tip to Solve: Check the gases and the temperature separately: the reducing mixture contains methane and ammonia, and the textbook value is 800 degrees Celsius.

11. Amniocentesis is a technique that is used to :

[1 mark]

- (A) determine any disease of the heart
- (B) determine any genetic disorder of the foetus
- (C) determine any disorder of the brain
- (D) detect any abnormality in the bone formation

Correct Answer: (B) determine any genetic disorder of the foetus

Solution:

Concept:

- Amniocentesis samples amniotic fluid containing foetal cells for prenatal examination.
- Analysis of these cells can identify chromosomal abnormalities and certain genetic disorders of the foetus.

Step 1: Connect the sample with the diagnostic purpose Foetal cells present in the amniotic fluid can be examined for their chromosomes and other genetic features. This makes amniocentesis a prenatal technique for detecting genetic abnormalities.

Step 2: Distinguish the alternatives The question asks for the characteristic purpose of this technique. General diagnosis of any heart disease, brain disorder or abnormal bone formation is not its defining use; the relevant category among the options is genetic disorders of the foetus.

Step 3: Conclusion Amniocentesis is used to determine genetic disorders of the foetus. Hence, the correct option is (B).

Quick Tip to Solve: Link amniotic fluid to foetal cells and their chromosomes to identify the purpose of amniocentesis.

12. In humans, non-disjunction of the 21st pair of chromosomes leads to :

[1 mark]

- (A) Acquired Immune Deficiency Syndrome
- (B) Klinefelter's Syndrome
- (C) Turner's Syndrome
- (D) Down's Syndrome

Correct Answer: (D) Down's Syndrome

Solution:

Concept:

- Non-disjunction is the failure of homologous chromosomes or sister chromatids to separate normally during cell division.
- An extra copy of chromosome 21 produces trisomy 21, the chromosomal basis of Down's syndrome.

Step 1: Trace the chromosomal consequence Failure of chromosome 21 to segregate normally can produce a gamete with two copies of this chromosome. Fertilisation by a normal gamete then produces a zygote with three copies of chromosome 21, giving 47 chromosomes in total.

Step 2: Identify the matching syndrome Trisomy 21 causes Down's syndrome. Klinefelter's syndrome typically involves 47, XXY, and Turner's syndrome involves 45, XO; these concern sex chromosomes. AIDS is caused by HIV infection, not chromosome 21 non-disjunction.

Step 3: Conclusion An extra chromosome 21 causes Down's syndrome. Hence, the correct option is (D).

Quick Tip to Solve: Match chromosome 21 with Down syndrome; match XXY and XO with sex-chromosome disorders.

13. Assertion (A) : *Streptococcus pneumoniae* and *Haemophilus influenzae* are responsible for causing infectious diseases in human beings.

Reason (R) : A healthy person acquires the infection by inhaling the droplets/aerosols released by an infected person. [1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

Solution:

Concept:

- Pneumonia is an infectious disease that can be caused by bacteria such as *Streptococcus pneumoniae* and *Haemophilus influenzae*.
- Respiratory droplets and aerosols can carry these pathogens from an infected person to a susceptible person.

Step 1: Judge the assertion Both *Streptococcus pneumoniae* and *Haemophilus influenzae* are bacterial pathogens that can cause pneumonia in humans. Thus, the assertion that they cause infectious diseases is true.

Step 2: Judge the reason A healthy person can acquire this infection by inhaling droplets or aerosols released by an infected person. This is a recognised mode of transmission of pneumonia, so the reason is true.

Step 3: Check the explanatory link The reason describes how these disease-causing organisms spread from an infected person to a healthy person. It therefore explains the infectious nature of the disease stated in the assertion. Options that deny either statement or deny this connection do not fit.

Step 4: Conclusion Both A and R are true, and R correctly explains A. Hence, the correct option is (A).

Quick Tip to Solve: For this pair, connect the word infectious in the assertion with the droplet-transmission route given in the reason.

14. Assertion (A) : Biotechnology produces transgenic micro-organisms that act as microfactories for proteins.

Reason (R) : To produce proteins for human use like insulin, transgenic microorganisms can be developed. [1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

Solution:

Concept:

- A transgenic microorganism contains an introduced gene whose product can be synthesised by the host cell.
- Recombinant microorganisms can produce human therapeutic proteins, including insulin, on a commercial scale.

Step 1: Judge the assertion Biotechnology introduces suitable protein-coding genes into microbial hosts. When these genes are expressed, the microorganisms synthesise the desired proteins and act as microfactories. The assertion is true.

Step 2: Judge the reason Transgenic microorganisms can be developed to produce proteins for human use, such as recombinant human insulin. Their cultures provide a controlled system for producing the required protein, so the reason is true.

Step 3: Check the explanatory link The ability to produce useful proteins such as insulin explains why transgenic microorganisms are described as protein microfactories. The example in the reason directly illustrates the function stated in the assertion, establishing the explanatory relationship.

Step 4: Conclusion Both A and R are true, and R correctly explains A. Hence, the correct option is (A).

Quick Tip to Solve: Connect microfactory with expression of an introduced protein-coding gene; insulin is the standard example.

15. Assertion (A) : Gross primary productivity is always less than net primary productivity.

Reason (R) : Rate of synthesis of organic matter by consumers is known as secondary productivity.

[1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (D) Assertion (A) is false, but Reason (R) is true.

Solution:

Concept:

- Gross primary productivity (GPP) is the total rate of organic matter production by photosynthesis.
- Net primary productivity (NPP) is what remains after respiratory losses: $NPP = GPP - R$, where R is producer respiration.

Step 1: Judge Assertion (A) Producers use part of the organic matter they synthesise for respiration. Therefore GPP exceeds NPP when respiratory losses are positive. The assertion reverses this relationship and is false.

Step 2: Judge Reason (R) Secondary productivity is the rate at which consumers form new organic matter or biomass. Thus the reason is true; it describes consumers, whereas the assertion concerns primary productivity in producers.

Step 3: Check the explanation and options Since A is false and R is true, neither option claiming that both statements are true is suitable. The option declaring R false also fails.

Step 4: Conclusion The assertion is false, but the reason is true. Hence, the correct option is (D).

Quick Tip to Solve: Write $NPP = GPP - \text{respiration}$ first; subtraction immediately shows which productivity is smaller.

16. Assertion (A) : Periodic abstinence is a method in which couples avoid coitus from day 10 to 17 of menstrual cycle.

Reason (R) : Periodic abstinence has limited effectiveness because menstrual cycles are not always regular. [1 mark]

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Assertion (A) is false, but Reason (R) is true.

Correct Answer: (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).

Solution:

Concept:

- Periodic abstinence avoids intercourse during the expected fertile period of a menstrual cycle.
- Variation in ovulation timing reduces the reliability of calendar-based contraception.

Step 1: Judge Assertion (A) In the textbook description of periodic abstinence, couples avoid coitus from day 10 to day 17 of the menstrual cycle, when the chances of fertilisation are high. Thus the assertion is true.

Step 2: Judge Reason (R) Menstrual cycles are not always regular, so the timing of ovulation and the fertile period can vary. Avoiding only the predicted days may therefore fail to prevent fertilisation. The reason is true.

Step 3: Test whether R explains A R explains the limited effectiveness of the method. It does not explain why days 10 to 17 are selected; those days are avoided because they cover the expected fertile period around ovulation. Thus R is not the correct explanation of A. Options with a false statement or an explanatory relation do not fit.

Step 4: Conclusion Both A and R are true, but R is not the correct explanation of A. Hence, the correct option is (B).

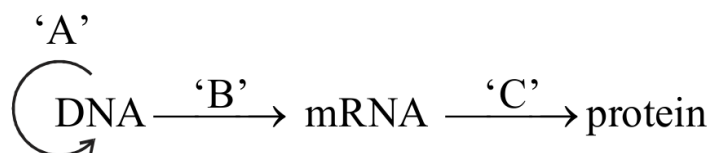
Quick Tip to Solve: For assertion-reason questions, separate the reason for choosing fertile days from the reason the method may fail.

Section B (10 marks)

17. (a) Given below is a representation of the “Central dogma” :

Identify ‘A’, ‘B’ and ‘C’ in the above representation.

(b) What does the Central dogma state in molecular biology ? Write an example where it is not applicable. [2 marks]



Solution:

Concept:

- Replication copies DNA, transcription makes RNA from a DNA template, and translation makes a polypeptide using an mRNA sequence.
- The usual direction of genetic information flow is DNA to RNA to protein.

Step 1: (a) Identify the labelled processes A is replication: the loop from DNA back to DNA represents copying of the genetic material. B is transcription: information in DNA is copied into mRNA. C is translation: the codon sequence of mRNA directs the amino acid sequence of a protein at ribosomes.

Step 2: (b) State the central dogma The central dogma, as represented here, states that genetic information flows from DNA to RNA and then to protein. DNA stores the information; mRNA carries the transcribed message; translation expresses it as a protein.

Step 3: Give the requested exception In retroviruses such as HIV, RNA serves as the template for DNA synthesis by reverse transcriptase. This flow, RNA to DNA, is called reverse transcription and is an exception to the simple one-way DNA-to-RNA scheme shown in the question.

Step 4: Conclusion A: replication; B: transcription; C: translation. Usual information flow is DNA to RNA to protein; retroviruses such as HIV show reverse transcription from RNA to DNA.

Quick Tip to Solve: Follow the arrow endpoints: DNA to DNA means replication, DNA to mRNA means transcription, and mRNA to protein means translation.

18. Why is making host cells ‘competent’ essential for rDNA technology ? Mention any two ways by which this can be achieved. [2 marks]

Solution:

Concept:

- DNA is hydrophilic and does not readily cross the lipid membrane of a host cell.
- A competent cell has been treated so that it can take up foreign DNA, including a recombinant vector.

Step 1: Explain why competence is essential In recombinant DNA technology, a recombinant DNA molecule must enter the host for cloning or expression. Simply mixing DNA with untreated cells is generally insufficient, because DNA cannot readily pass through the cell membrane. Making cells competent enables uptake of the recombinant DNA and hence transformation.

Step 2: First method: chemical treatment and heat shock Bacterial cells can be treated with a suitable concentration of divalent calcium ions, which increases their ability to take up DNA. The cells are incubated with recombinant DNA on ice, briefly heat-shocked at 42°C, and then returned to ice.

Step 3: Second method: electroporation A brief electrical pulse creates temporary pores in the cell membrane. Recombinant DNA can enter through these pores, after which the membrane reseals and the cells are allowed to recover.

Step 4: Conclusion Competence is required for entry of recombinant DNA into host cells. Calcium-ion treatment followed by heat shock, and electroporation, are two ways to achieve DNA uptake.

Quick Tip to Solve: Link each method to DNA entry: calcium treatment plus heat shock assists uptake; an electrical pulse opens temporary pores.

19(a). Comment on the interaction between a fig tree and wasp. Mention the phenomenon that operates in their relationship. [2 marks]

Solution:

Concept:

- Mutualism is an interspecific interaction in which both partners benefit.
- Coevolution occurs when interacting species evolve adaptations in response to one another.

Step 1: Explain the benefit to the fig tree The female fig wasp enters the fig inflorescence to lay her eggs. While doing so, she pollinates the flowers, enabling the fig tree to form seeds. The tree therefore receives a reproductive benefit from the wasp.

Step 2: Explain the benefit to the wasp The fig provides a suitable site for egg laying and a place for the larvae to develop. Some developing seeds serve as food for the larvae. Thus the wasp obtains a breeding site and nourishment for its offspring while the fig obtains pollination.

Step 3: Name the phenomenon operating This specialised association is mutualism and illustrates coevolution. The fig and its pollinating wasp have evolved closely matched reproductive adaptations; the dependence of the wasp on the fig and of the fig on its pollinator favours reciprocal evolutionary changes.

Step 4: Conclusion The fig tree and wasp show mutualism: pollination benefits the fig, while a breeding site and larval food benefit the wasp. Their specialised relationship illustrates coevolution.

Quick Tip to Solve: State both benefits before naming coevolution: fig receives pollination; wasp receives a breeding site and food for larvae.

19(b). Explain “brood parasitism” with the help of an example.

[2 marks]

Solution:

Concept:

- Brood parasitism is an interaction in which a bird uses another bird to incubate its eggs and rear its young.
- The parasite gains parental care while the host spends time, energy and food on offspring that are not its own.

Step 1: Explain the interaction A brood-parasitic bird lays its eggs in the nest of a host bird instead of incubating them and caring for the chicks itself. The host incubates the eggs along with its own and subsequently feeds and protects the young parasite. Thus, reproductive investment is transferred from the parasite to the host, which bears the cost of caring for the unrelated offspring.

Step 2: Illustrate with the cuckoo and crow The cuckoo (koel) lays its eggs in the nest of a crow. The crow acts as the host, incubating the eggs and rearing the cuckoo chicks. During evolution, the eggs of the parasitic bird have come to resemble the host eggs in size and colour; this reduces detection and rejection by the host.

Step 3: Conclusion Brood parasitism is exemplified by the cuckoo laying eggs in a crow nest and obtaining incubation and care of its young from the crow.

Quick Tip to Solve: Name both birds and explicitly state that the host incubates eggs and rears the parasite young.

20. State the cellular nature and functions of myometrium and endometrium.

[2 marks]

Solution:

Concept:

- The uterine wall has an outer perimetrium, a middle myometrium and an inner endometrium.
- The myometrium provides muscular force; the endometrium provides a hormonally responsive surface for implantation and pregnancy.

Step 1: Myometrium: cellular nature and function The myometrium is the thick middle layer of the uterine wall, composed mainly of smooth muscle cells. These involuntary muscle cells generate the strong uterine contractions during childbirth that help expel the fully developed foetus from the uterus.

Step 2: Endometrium: cellular nature and function The endometrium is the inner glandular lining of the uterus, with glandular epithelium and a vascular supporting stroma. It undergoes cyclic changes during the menstrual cycle under ovarian hormones. It thickens and becomes secretory to receive the blastocyst, permit implantation and support early embryonic nourishment. If pregnancy does not occur, its functional layer is shed during menstruation.

Step 3: Conclusion Myometrium is a smooth-muscle layer responsible for strong parturition contrac-

tions; endometrium is the inner glandular lining that changes cyclically and supports implantation and early pregnancy.

Quick Tip to Solve: Link muscle to childbirth contractions and the inner glandular lining to menstrual changes and implantation.

21. How do 'implants' act as an effective method of contraception in human females ? Mention their one advantage over contraceptive pills. [2 marks]

Solution:

Concept:

- Hormonal implants are small preparations placed beneath the skin that release progestogens, either alone or combined with oestrogens.
- Their contraceptive action is hormonal and sustained, reducing the need for repeated user action.

Step 1: Explain the contraceptive action Implants release contraceptive hormones slowly into the body over an extended period. Their sustained hormonal action inhibits ovulation and makes the endometrium unsuitable for implantation. They also alter cervical mucus, making it thicker and less favourable for the entry and passage of sperm. Together, these effects reduce the chances of fertilisation and establishment of pregnancy.

Step 2: State an advantage over pills An implant provides effective contraception for a much longer period after a single insertion, whereas oral contraceptive pills must be taken regularly according to a schedule. It therefore avoids the need to remember a pill each day and reduces failure caused by missed daily doses. The implant is inserted by a trained health-care provider.

Step 3: Conclusion Implants act by sustained hormonal inhibition of ovulation, reduced suitability for implantation and altered cervical mucus; their advantage is long-duration protection without daily pill-taking.

Quick Tip to Solve: Give the hormonal mechanisms first, then contrast one implant insertion with remembering a daily pill.

Section C (21 marks)

22. Differentiate between :

(a) Grazing food chain and Detritus food chain (Any three differences)

(b) Upright pyramid and Inverted pyramid (Any three differences)

[3 marks]

Solution:

Concept:

- A food chain describes transfer of food and energy through successive trophic levels.
- An ecological pyramid compares the number, biomass or energy of organisms at successive trophic levels; its shape depends on the parameter measured.

Step 1: (a) Grazing and detritus food chains: three differences First, a grazing food chain begins with living green producers, whereas a detritus food chain begins with dead organic matter such as fallen leaves and animal remains. Second, the first consumers in a grazing chain are herbivores feeding directly on plants; in a detritus chain, the dead material is used by decomposers such as bacteria and fungi and by detritivores. Third, a grazing chain is fuelled directly by the current photosynthetic production of its producers, whereas a detritus chain uses chemical energy stored in previously formed organic matter. For example, grass to deer to tiger represents a grazing chain, while dead leaves to earthworm to bird represents a detritus chain.

Step 2: (b) Upright and inverted pyramids: three differences First, an upright pyramid has a broad producer base and narrows towards higher trophic levels; an inverted pyramid has a relatively narrow producer base and widens towards higher levels. Second, in an upright pyramid the quantity represented is greatest at the producer level and decreases at higher levels, whereas in an inverted pyramid a higher consumer level has a greater represented quantity than the level below it. Third, an example is the upright pyramid of biomass in a grassland, where plant biomass exceeds herbivore biomass, compared with the inverted pyramid of biomass in an aquatic ecosystem, where the standing biomass of phytoplankton may be smaller than that of zooplankton supported by their rapid turnover. These comparisons concern the same measured parameter: biomass. A pyramid of energy is always upright because usable energy decreases at every trophic transfer; it cannot be inverted.

Step 3: Conclusion Grazing and detritus chains differ in starting material, first feeding organisms and immediate energy source. Upright and inverted pyramids differ in shape, the distribution of the measured quantity and ecosystem examples.

Quick Tip to Solve: Specify whether a pyramid represents numbers, biomass or energy; never describe an energy pyramid as inverted.

23(a). (i) What are “biodiversity hotspot” regions ? Mention any two criteria used for determining any region as a “hotspot”.

(ii) Name any two hotspots of India.

[3 marks]

Solution:

Concept:

- Biodiversity hotspots are regions with exceptionally high species richness and a high degree of endemism which face severe habitat loss and threat.
- Endemic species occur naturally only in a particular geographical region. Hotspot status identifies areas where conservation can protect many unique threatened species.

Step 1: Identify hotspot regions A biodiversity hotspot is a region containing a very rich assemblage of species, especially species restricted to that region, whose natural habitat has undergone extensive destruction. Such areas are priorities for conservation because loss of their habitat may cause the global extinction of their endemic species.

Step 2: State two criteria The two principal criteria are high endemism and a high degree of threat caused by habitat loss. Quantitatively, a region must contain at least 1,500 endemic vascular plant

species and must have lost at least 70 percent of its original natural vegetation. Thus, richness alone is insufficient: the concentration of unique species and the extent of habitat destruction together determine hotspot status.

Step 3: Name two Indian hotspots Two hotspots that include Indian territory are the Western Ghats and Sri Lanka hotspot, and the Himalaya hotspot. The Western Ghats and the Indian Himalayan region contain numerous endemic species and have experienced substantial habitat loss.

Step 4: Conclusion Hotspots combine high endemism with severe habitat loss. Two examples in India are the Western Ghats and the Himalaya.

Quick Tip to Solve: Remember both selection criteria: unique endemic species and extensive loss of their natural habitat.

OR

23(b). Explain giving three reasons, why tropics show greatest level of species diversity. [3 marks]

Solution:

Concept:

- The latitudinal diversity gradient means that species richness generally increases from the poles towards the equator.
- Tropical diversity is explained by long evolutionary time, a relatively stable climate and high solar energy supporting greater productivity.

Step 1: Long uninterrupted evolutionary time Unlike temperate regions, which experienced repeated glaciations in the past, tropical regions remained relatively undisturbed for millions of years. This long evolutionary history provided more time for speciation and the accumulation of species. Repeated disturbance and extinction in colder regions reduced the opportunity for comparable accumulation.

Step 2: Stable and predictable environment Tropical environments are comparatively less seasonal, more constant and more predictable than temperate environments. Such conditions favour niche specialisation: species can become adapted to particular resources and microhabitats. This allows more specialised species to coexist and contributes to high species richness.

Step 3: Greater solar energy and productivity The tropics receive more solar energy over the year. Greater light availability supports higher primary productivity by photosynthetic organisms. This provides a larger resource base that can sustain more organisms and a greater variety of ecological niches, contributing indirectly to greater species diversity.

Step 4: Conclusion The tropics have greatest species diversity because of long evolutionary time, a relatively stable climate promoting niche specialisation, and greater solar energy supporting high productivity.

Quick Tip to Solve: For the three reasons, recall evolutionary time, climatic stability and solar energy, and explain how each increases diversity.

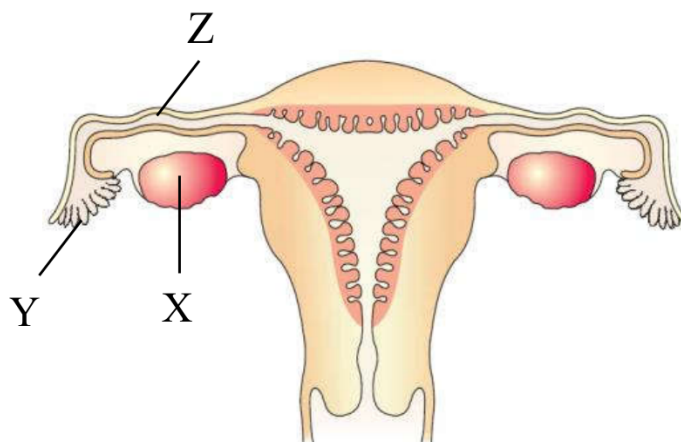
24. Given below is the diagram showing a part of the reproductive system of a human female.

(a) Identify 'Y' and write its function.

(b) Identify 'Z' and write the events that may occur here.

(c) Mention the stage at which the process of oogenesis temporarily gets arrested and name the cells thus formed in the 'X' of a baby girl at the time of her birth.

[3 marks]



Solution:

Concept:

- The ovary produces oocytes; the fimbriae at the funnel-shaped end of the oviduct help collect the oocyte released at ovulation.
- The oviduct transports the female gamete, is the site of fertilisation at its ampullary-isthmic junction, and supports early cleavage of the zygote.
- In fetal life, oogonia enter meiosis I and become primary oocytes, which remain arrested in prophase I until their subsequent maturation.

Step 1: (a) Identify Y and explain its function Y indicates the fimbriae, the finger-like projections at the margin of the infundibulum of the fallopian tube. They help collect the secondary oocyte released from the ovary during ovulation and guide it into the oviduct. They thereby bring the released gamete into the passage where it can meet sperm.

Step 2: (b) Identify Z and state the events Z indicates the fallopian tube or oviduct. Fertilisation may occur at the ampullary-isthmic junction when a sperm fuses with the secondary oocyte to form a zygote. The zygote then undergoes successive mitotic cleavage divisions as it travels towards the uterus, forming early blastomeres and subsequently a morula. Thus, fertilisation and early embryonic cleavage are the important events associated with this tube.

Step 3: (c) State the arrest stage and name the cells in X X is the ovary. During fetal development, oogonia begin meiosis I and form primary oocytes. Their meiotic division is temporarily arrested in prophase I, specifically the diplotene stage. Therefore, the cells present in this arrested state in the ovaries of a baby girl at birth are primary oocytes, not secondary oocytes or mature ova.

Step 4: Conclusion Y: fimbriae that collect the ovulated oocyte; Z: oviduct, where fertilisation and early cleavage occur; X: ovary containing primary oocytes arrested in prophase I at birth.

Quick Tip to Solve: Distinguish the birth stage from ovulation: primary oocytes arrest in prophase I, whereas secondary oocytes arrest in metaphase II.

25. (a) What is gene therapy ?

(b) Describe the procedure of such a therapy that could be a permanent cure for a genetic disease. Name the genetic disease. [3 marks]

Solution:

Concept:

- Gene therapy treats a genetic disorder by introducing a functional gene into the cells of an affected individual to compensate for a defective gene.
- Adenosine deaminase (ADA) deficiency is caused by a defective gene for the enzyme ADA, which is needed for normal immune function.

Step 1: Define gene therapy: part (a) Gene therapy is the correction or compensation of a genetic defect by delivering a normal, functional gene into the patient's cells. The introduced gene expresses the functional product that the defective gene cannot supply.

Step 2: Explain the cellular procedure: part (b) For ADA deficiency, lymphocytes are isolated from the patient's blood and grown in a culture outside the body. A functional ADA cDNA is introduced into these lymphocytes using a retroviral vector, and the genetically engineered lymphocytes are returned to the patient. They can now produce functional ADA. However, these lymphocytes are not immortal, so this treatment requires periodic infusions of engineered cells.

Step 3: Identify the route to a permanent cure For a permanent cure, a functional ADA gene isolated from suitable cells is introduced into cells at an early embryonic stage. Its stable incorporation allows the developing cell lineages to carry and express the functional gene, instead of providing ADA only through short-lived, repeatedly infused lymphocytes. The disease named here is ADA deficiency.

Step 4: Conclusion Gene therapy introduces a functional gene to compensate for a defective one. In ADA deficiency, introduction of a functional ADA gene into cells at an early embryonic stage could provide a permanent cure.

Quick Tip to Solve: Distinguish repeated infusion of engineered lymphocytes from early embryonic gene introduction when the question asks for a permanent cure.

26. Differentiate between the explanations given by Darwin and de Vries respectively on the mechanism of evolution. Write any three differences. [3 marks]

Solution:

Concept:

- Darwin explained evolution by natural selection acting on heritable variations in populations.
- Hugo de Vries proposed mutation theory: sudden, large, heritable changes can produce new forms.

Step 1: Difference 1: nature of variation According to Darwin's explanation, small heritable variations among individuals provide the material on which natural selection acts. In de Vries' explanation, mutations are sudden, large and discontinuous variations. Thus the contrast is between small variations accumulated through selection and abrupt mutational changes.

Step 2: Difference 2: direction of variation Darwin's account describes small directional variations being favoured and accumulated through natural selection. In contrast, de Vries considered mutations to be random and directionless: their appearance does not occur because an organism needs a particular adaptation. The directionality in Darwin's account refers to the changes retained through selection, rather than a conscious response by individuals.

Step 3: Difference 3: pace and origin of species Darwin regarded evolution as gradual: favourable inherited variations accumulate over many generations and may eventually lead to new species. De Vries proposed that speciation could occur through a single large mutational change, called saltation. Therefore gradual accumulation in Darwin's explanation contrasts with sudden, discontinuous origin in mutation theory.

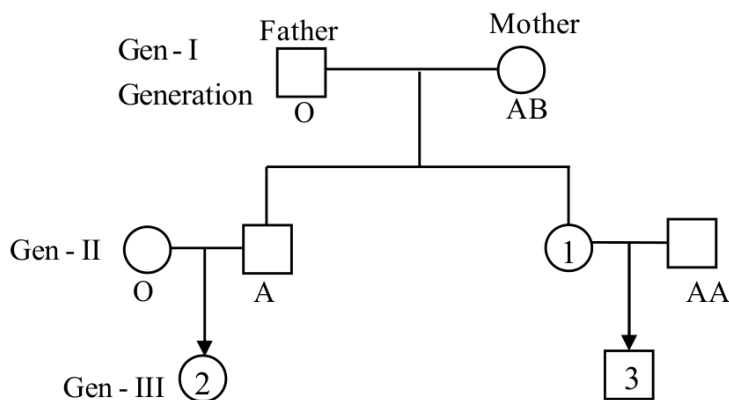
Step 4: Conclusion The three differences are: small versus large discontinuous variations; directional accumulation versus random, directionless mutations; and gradual evolution versus sudden speciation by saltation.

Quick Tip to Solve: Organise the comparison under variation size, direction and evolutionary pace; attribute saltation to de Vries.

27. Given below is the pedigree chart up to 3 generations (Generation I, Generation II, Generation III) of a family with respect to their blood groups.

- (a) Mention the blood group along with the genotype of the offspring numbered '1' in Generation II.
 (b) Write the possible blood groups along with their genotypes of the offsprings numbered '2' and '3' in Generation III.

[3 marks]



Solution:

Concept:

- The ABO blood group alleles are I^A , I^B and i . Alleles I^A and I^B are codominant, and each is dominant over i .
- Group O has genotype ii , group AB has $I^A I^B$, group A has $I^A I^A$ or $I^A i$, and group B has $I^B I^B$ or $I^B i$.

Step 1: Find the possibilities for individual 1: part (a) The Generation I father is group O, ii , and

the mother is group AB, $I^A I^B$. The father supplies only i , while the mother supplies either I^A or I^B . Hence individual 1 can be group A with genotype $I^A i$, or group B with genotype $I^B i$. The pedigree does not uniquely choose between these two possibilities.

Step 2: Find the possibilities for individual 2: part (b) The group A son in Generation II must have genotype $I^A i$, since his group O father supplied i . His partner is group O, ii . The cross $I^A i \times ii$ gives $I^A i$ and ii . Thus individual 2 may have group A, $I^A i$, or group O, ii .

Step 3: Find the possibilities for individual 3: part (b) The partner of individual 1 is labelled AA, so his genotype is $I^A I^A$. If individual 1 is $I^A i$, the cross gives $I^A I^A$ or $I^A i$, both group A. If individual 1 is $I^B i$, the cross gives $I^A I^B$, group AB, or $I^A i$, group A. Taking both possible genotypes of individual 1, individual 3 can therefore be group A with $I^A I^A$ or $I^A i$, or group AB with $I^A I^B$.

Step 4: Conclusion Individual 1: A ($I^A i$) or B ($I^B i$). Individual 2: A ($I^A i$) or O (ii). Individual 3: A ($I^A I^A$ or $I^A i$) or AB ($I^A I^B$).

Quick Tip to Solve: Every child of the Generation I O parent inherits i ; retain both possible genotypes of individual 1 when deriving individual 3.

28. (a) Name the enzyme responsible for the transcription of tRNA.

(b) Draw a labelled diagram of an initiator tRNA charged with its respective amino acid.

(c) Explain the role of the initiator tRNA in initiation of protein synthesis.

[3 marks]

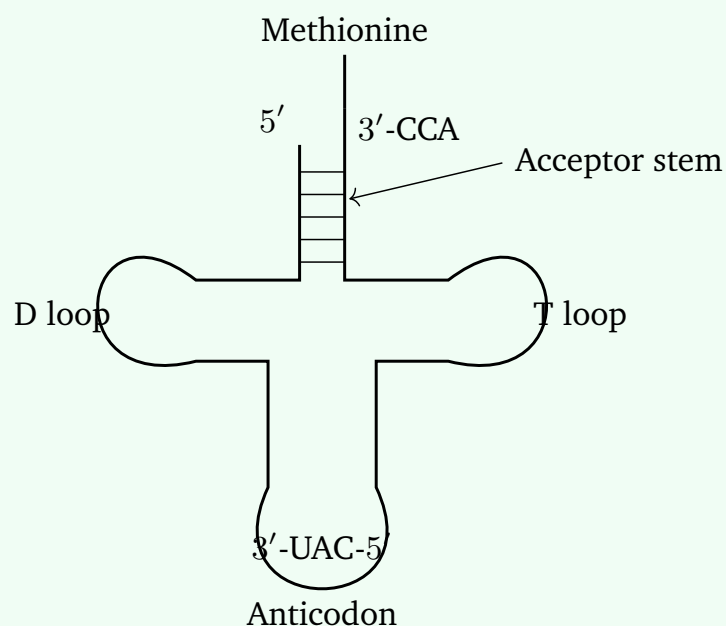
Solution:

Concept:

- In eukaryotes, RNA polymerase III transcribes tRNA genes. Transfer RNA acts as an adaptor between an mRNA codon and an amino acid.
- The initiator tRNA carries methionine and has an anticodon complementary to the initiation codon 5'-AUG-3'.

Step 1: Identify the transcription enzyme (a) The enzyme responsible for transcription of tRNA is RNA polymerase III in eukaryotic cells. This differs from RNA polymerase II, which transcribes the precursor of mRNA.

Step 2: Represent the charged initiator tRNA (b) The labelled cloverleaf diagram shows methionine attached to the terminal adenosine of the 3'-CCA acceptor end. The anticodon is 3'-UAC-5', written antiparallel to the start codon. The D loop and T loop are also labelled.



Methionine-charged initiator tRNA (cloverleaf representation)

Step 3: Explain initiation (c) The small ribosomal subunit binds the mRNA. The charged initiator tRNA recognises the start codon AUG through complementary pairing of its UAC anticodon. It brings methionine, the first amino acid, to the initiation complex. Association of the large ribosomal subunit places the initiator tRNA at the P site and leaves the A site available for the next aminoacyl-tRNA. This establishes the reading frame and allows elongation to begin.

Step 4: Conclusion RNA polymerase III transcribes tRNA; the methionine-charged initiator tRNA recognises AUG and initiates the polypeptide chain.

Quick Tip to Solve: Remember the adaptor ends: amino acid at the 3'-CCA end, anticodon in the opposite loop.

Section D (8 marks)

Questions No. 29 and 30 are case-based questions. Each question has 3 sub-questions with internal choice in one sub-question.

29(a). Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology. Name the first isolated restriction endonuclease. Why are restriction endonucleases so called ?

[1 mark]

Solution:

Concept:

- Restriction enzymes protect bacteria by restricting the multiplication of foreign DNA, such as bacteriophage DNA.
- An endonuclease cleaves phosphodiester bonds at internal positions in a DNA molecule.

Step 1: Name the first isolated enzyme The first restriction endonuclease isolated and characterised was Hind II. It recognises a specific DNA sequence and cuts DNA at a defined position.

Step 2: Explain the name They are called restriction endonucleases because they restrict the growth of bacteriophages by cutting foreign DNA internally. The term endonuclease distinguishes internal cleavage from removal of nucleotides at the ends by exonucleases.

Step 3: Conclusion The enzyme is Hind II; restriction endonucleases restrict foreign DNA by cleaving it internally.

Quick Tip to Solve: Link the two words separately: restriction of foreign DNA, and internal cleavage by an endonuclease.

29(b). Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology. Write the palindrome recognised by EcoRI.

[1 mark]

Solution:

Concept:

- A DNA palindrome has the same sequence when each complementary strand is read in the 5' to 3' direction.
- EcoRI recognises a specific sequence of six base pairs, rather than any arbitrary AT-rich sequence.

Step 1: Write the two complementary strands The palindromic recognition site of EcoRI is

5'-GAATTC-3'

3'-CTTAAG-5'

The two strands are antiparallel and obey complementary base pairing.

Step 2: Check the palindrome Reading the upper strand from left to right gives GAATTC. Reading the lower strand from right to left, also in the 5' to 3' direction, gives GAATTC again. This directional identity is the defining feature of the recognised palindrome.

Step 3: Conclusion EcoRI recognises 5'-GAATTC-3', paired with 3'-CTTAAG-5'.

Quick Tip to Solve: Always write both complementary strands with end labels; read each strand from 5' to 3'.

29(c)(i). Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology. How does restriction endonuclease function ? Explain. [2 marks]

Solution:

Concept:

- Restriction endonucleases recognise particular short DNA sequences, commonly palindromic sequences.
- They hydrolyse phosphodiester bonds in the DNA backbone at defined positions, producing DNA fragments.

Step 1: Recognise the target sequence The restriction endonuclease binds DNA and checks its nucleotide sequence. When it encounters its specific recognition sequence, it associates with that site. Recognition is sequence-specific: an enzyme does not cut every phosphodiester bond or any sequence that happens to resemble its target.

Step 2: Cut the DNA backbone The enzyme cleaves phosphodiester bonds at defined positions in both strands of DNA. For example, EcoRI cuts between G and A in its GAATTC recognition sequence on each strand. The staggered cuts generate single-stranded AATT overhangs, called sticky ends. Other restriction endonucleases may produce blunt ends. Complementary sticky ends of DNA fragments cut with the same enzyme can base-pair, and DNA ligase then seals the sugar-phosphate backbone during recombinant DNA formation.

Step 3: Conclusion A restriction endonuclease recognises a specific sequence and cleaves the DNA internally at defined sites, producing fragments with sticky or blunt ends.

Quick Tip to Solve: State recognition first and phosphodiester-bond cleavage second; sticky ends can then pair with matching ends.

29(c)(ii). Restriction endonuclease was isolated for the first time by W. Arber in 1962, in bacteria. DNA, the genetic material can be manipulated by addition or substitution of the desired gene by using a specific restriction endonuclease resulting in rDNA. This is one of the major steps in biotechnology. Write the convention for naming a restriction endonuclease with the help of an example. [2 marks]

Solution:

Concept:

- Restriction endonucleases are named after the bacterial organism from which they are isolated.
- The name records the genus, species, strain and order of isolation of the enzyme.

Step 1: Identify the organism and strain In the name EcoRI, E comes from the first letter of the genus Escherichia and co from the first two letters of the species coli. Thus, Eco identifies Escherichia coli. The genus letter is capitalised, while the two species letters are lowercase.

Step 2: Identify the strain and isolation order The letter R identifies the bacterial strain, E. coli RY13. The Roman numeral I indicates that EcoRI was the first restriction endonuclease isolated from that strain. A later enzyme isolated from the same strain would receive the next Roman numeral; the numeral does not indicate its recognition-site length.

Step 3: Conclusion For EcoRI: E = Escherichia, co = coli, R = strain RY13 and I = first enzyme isolated from that strain.

Quick Tip to Solve: Decode EcoRI in four parts: genus, species, strain and isolation order.

30(a). A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

What are the symptoms seen in the student indicative of ? Elaborate.

[1 mark]

Solution:

Concept:

- Allergy is an exaggerated immune response to certain antigens, called allergens, present in the environment.
- Sneezing, watery eyes and breathing difficulty are characteristic allergic symptoms.

Step 1: Identify the response The rapid appearance of sneezing, watery eyes and difficulty in breathing after the spray suggests an allergic response to a component of the deodorant.

Step 2: Explain the response In a sensitised person, an otherwise harmless environmental substance acts as an allergen and triggers an exaggerated immune response. IgE antibodies participate in this reaction, which leads to release of inflammatory mediators and the observed symptoms.

Step 3: Conclusion The symptoms indicate allergy: hypersensitivity to an allergen in the deodorant.

Quick Tip to Solve: Link the immediate symptoms after exposure to an exaggerated immune response.

30(b). A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

State how the cause of such responses can be confirmed.

[1 mark]

Solution:

Concept:

- A suspected allergen is identified by observing a specific allergic response during a controlled diagnostic test.
- The history of exposure suggests which substances should be tested.

Step 1: Select the suspected allergen The history points to a component of the deodorant as the suspected allergen. The exposure history alone suggests the cause but does not establish which ingredient is responsible.

Step 2: Confirm by an allergy test Under medical supervision, very small doses of suspected allergens can be introduced into the skin and the resulting response studied. A characteristic local reaction, such as redness and swelling to the relevant substance, supports identification of the allergen responsible.

Step 3: Conclusion Confirm the cause by testing very small doses of suspected allergens and studying the allergic response under medical supervision.

Quick Tip to Solve: State the diagnostic principle: a tiny test dose followed by observation of the response.

30(c)(i). A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

Name the cells in our body and the chemicals produced by them that are responsible for such reactions. Name any two drugs used to reduce these symptoms.

[2 marks]

Solution:

Concept:

- Mast cells release chemical mediators that produce the symptoms of allergy.
- Antihistamines and steroids are drugs used to reduce allergic symptoms.

Step 1: Name the cells and their chemicals Mast cells are responsible for the release of histamine and serotonin during an allergic response. In a sensitised individual, interaction of the allergen with the IgE-associated response triggers release of these mediators. They bring about inflammatory changes responsible for symptoms such as sneezing, watery eyes and difficulty in breathing.

Step 2: Name two drugs Antihistamines and steroids are two classes of drugs used to reduce these symptoms. Antihistamines counter the effects of histamine, while steroids reduce the inflammatory response. Thus, the treatment targets the effects of the released mediators and the associated

inflammation.

Step 3: Conclusion Cells: mast cells. Chemicals: histamine and serotonin. Two drugs: antihistamines and steroids.

Quick Tip to Solve: Pair mast cells with histamine and serotonin, then name two drug classes.

OR

30(c)(ii). A senior student, sneezing very badly, with watery eyes and having difficulty in breathing was brought to the school medical room by his fellow friends. The medical room nurse enquired as to what had happened. One of the students said “after the football match we all were sweating profusely, one of our friends sprayed deodorant on us. Soon after the deodorant was sprayed on the senior boy, the symptoms appeared.”

‘In recent times there is a rise in such reactions amongst urban human population.’ Do you agree ? Give three reasons in support of your answer. [2 marks]

Solution:

Concept:

- Allergies involve hypersensitivity to environmental allergens.
- Urban lifestyle and environmental changes can increase susceptibility and exposure to allergens.

Step 1: State agreement and explain reduced early exposure Yes. A rise in allergic reactions in urban populations is consistent with changes in lifestyle and environment. First, an increasingly protected environment in early life can reduce exposure to the normal range of environmental microbes and antigens, predisposing the immune system to inappropriate hypersensitivity responses.

Step 2: Give two further reasons Second, modern urban lifestyles include greater use of synthetic products such as deodorants, cosmetics and household chemicals, increasing contact with potential allergens. Third, increased urban air pollution exposes the respiratory tract to pollutants and airborne particles that can promote or aggravate allergic responses. These factors help explain the increased frequency of such reactions; they do not mean every urban individual will develop an allergy.

Step 3: Conclusion Yes. A protected early environment, increased exposure to synthetic products and greater urban air pollution can contribute to the rise in allergic reactions.

Quick Tip to Solve: Give three distinct factors: protected early life, synthetic products and polluted air.

Section E (15 marks)

31(a). Describe the process of wastewater (sewage) treatment under the following heads :

(i) Primary treatment

(ii) Secondary treatment

[5 marks]

Solution:

Concept:

- Primary sewage treatment physically removes floating and suspended solids by filtration and sedimentation.
- Secondary treatment uses microorganisms to consume organic matter. Biochemical oxygen demand (BOD) measures the oxygen required by aerobic microbes to oxidise organic matter in water; a lower BOD indicates a reduced organic load.

Step 1: (i) Primary treatment: physical separation Sewage is first passed through screens or filters to remove floating debris. It then passes through a grit-removal stage, where soil, sand and small pebbles settle. In a sedimentation tank, suspended solids settle to the bottom as primary sludge. The liquid above the settled material is the primary effluent. Thus, filtration and sedimentation remove particles before biological treatment; this stage does not depend on microbial decomposition.

Step 2: (ii) Secondary treatment: aeration and microbial growth The primary effluent enters large aeration tanks, where it is constantly agitated mechanically and air is pumped into it. This promotes the vigorous growth of useful aerobic microbes as flocs: masses of bacteria associated with fungal filaments to form mesh-like structures. As these microbes grow, they consume much of the organic matter present in the effluent. Consequently, its BOD is significantly reduced. Aeration continues until the organic load has fallen sufficiently.

Step 3: (ii) Settling, recycling and sludge digestion The treated effluent is transferred to a settling tank, where the bacterial flocs settle as activated sludge. A small portion of this sludge is pumped back into the aeration tank as an inoculum. Most of the remaining sludge is sent to anaerobic sludge digesters. Anaerobic bacteria digest the bacteria and fungi in the sludge and produce a mixture of gases, including methane, carbon dioxide and hydrogen sulphide, which forms biogas. After secondary treatment, the much cleaner effluent is generally released into natural water bodies such as rivers and streams in accordance with treatment requirements.

Step 4: Conclusion Primary treatment removes sewage solids physically, while secondary treatment uses microbial activity to lower BOD, followed by settling of activated sludge and anaerobic digestion of the excess sludge.

Quick Tip to Solve: Recall the sequence: screens and settling, aeration with flocs, activated-sludge settling, then recycling and anaerobic digestion.

31(b). (i) Explain the sequence of events occurring in a biogas plant.

(ii) Write the components of biogas.

(iii) Write any three advantages of using cow dung as the raw material.

[5 marks]

Solution:

Concept:

- Biogas is produced by anaerobic microbial digestion of organic matter. Methanogens such as *Methanobacterium* produce methane and occur naturally in cattle dung.
- The plant provides an oxygen-free digester, a gas-collection arrangement and an outlet for the nutrient-rich spent slurry, allowing both fuel and manure to be obtained.

Step 1: (i) Preparation and anaerobic digestion Cattle dung is mixed with water to make a slurry, which is fed through an inlet into a concrete digestion tank. The tank is closed so that digestion takes place under anaerobic conditions. Microorganisms break down the complex organic matter into simpler substances; methanogenic microbes then act on suitable breakdown products and generate methane-rich biogas. Cattle dung already contains many of these useful microbes, so it supplies both decomposable material and a microbial inoculum.

Step 2: (i) Collection of gas and removal of slurry The gas produced accumulates above the slurry. In a plant with a floating cover, the cover rises as the gas collects. A pipe connected to the gas holder supplies biogas for use as fuel, for example in cooking and lighting. The spent slurry comes out through an outlet or overflow arrangement and can be collected and used as manure. Thus, fresh slurry input, microbial digestion, gas collection and spent-slurry removal form the operating sequence.

Step 3: (ii) Components of biogas Biogas is a mixture containing mainly methane, together with carbon dioxide and small quantities of gases such as hydrogen and hydrogen sulphide. Methane is the principal combustible component responsible for its usefulness as a fuel.

Step 4: (iii) Three advantages of cow dung as raw material First, cow dung is readily available and inexpensive in cattle-rearing rural areas, providing a regular supply of raw material. Second, it contains abundant methanogens derived from the cattle rumen, so it naturally supplies microbes needed for methane production as well as organic substrate. Third, its digestion leaves nutrient-rich slurry that can be used as manure; thus, fuel can be obtained while retaining a useful fertiliser product from the dung.

Step 5: Conclusion Anaerobic digestion of dung slurry yields methane-rich biogas for fuel and spent slurry for manure. Cow dung is economical, naturally supplies methanogens and provides useful manure after digestion.

Quick Tip to Solve: Organise this answer as plant sequence, gas composition, then three distinct advantages of the dung feedstock.

32(a). (i) Draw a labelled diagram of a fertilised embryo sac of an angiosperm. (label any four parts)

(ii) Explain double fertilisation in angiospermic plant.

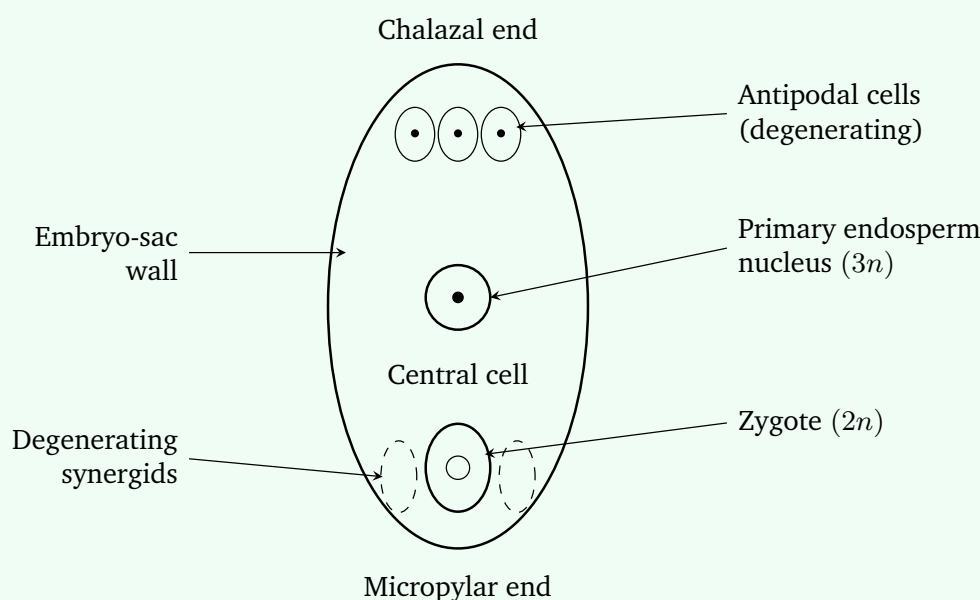
[5 marks]

Solution:

Concept:

- Double fertilisation comprises two fusion events within the same embryo sac: syngamy and triple fusion. Both male gametes delivered by one pollen tube participate.
- Syngamy forms the diploid zygote, whereas triple fusion forms the triploid primary endosperm nucleus. Here n denotes one haploid chromosome set.

Step 1: (i) Labelled fertilised embryo sac The diagram shows the embryo sac immediately after the two fertilisation events, before extensive embryo or endosperm development. The zygote occupies the micropylar end, and the primary endosperm nucleus lies in the large central cell. Antipodal cells occupy the chalazal end and subsequently degenerate; the synergids at the micropylar end also degenerate. The labels distinguish the products of fertilisation from these remaining accessory cells.



Fertilised embryo sac immediately after double fertilisation (schematic)

Step 2: (ii) Delivery of the male gametes After compatible pollination, the pollen grain germinates on the stigma. Its pollen tube grows through the style and enters an ovule, usually through the micropyle. It enters a synergid through the filiform apparatus and releases two male gametes into the embryo sac. One gamete moves towards the egg and the other towards the central cell.

Step 3: Syngamy produces the zygote One male gamete fuses with the egg cell. Fusion of their haploid nuclei produces the diploid zygote:



This fusion is called syngamy. The zygote subsequently develops into the embryo of the seed.

Step 4: Triple fusion initiates endosperm formation The second male gamete fuses with the two polar

nuclei in the central cell, or with their already fused diploid secondary nucleus:

Male gamete (n) + two polar nuclei ($n + n$) $\longrightarrow$ primary endosperm nucleus ($3n$).

Because three haploid nuclear contributions unite, this event is called triple fusion. The central cell becomes the primary endosperm cell; its divisions produce endosperm that nourishes the developing embryo. Endosperm development normally precedes embryo development, providing a nutritional supply for the embryo.

Step 5: Conclusion Syngamy and triple fusion occurring in the same embryo sac together constitute double fertilisation, a characteristic feature of angiosperms. Their immediate products are the diploid zygote and the triploid primary endosperm nucleus, respectively.

Quick Tip to Solve: In a fertilised embryo sac, label the zygote and primary endosperm nucleus, rather than an unfertilised egg and polar nuclei.

OR

32(b). (i) Draw a labelled diagram of a cross-section of human seminiferous tubule. (label any four parts)

(ii) Explain the hormonal regulation of spermatogenesis.

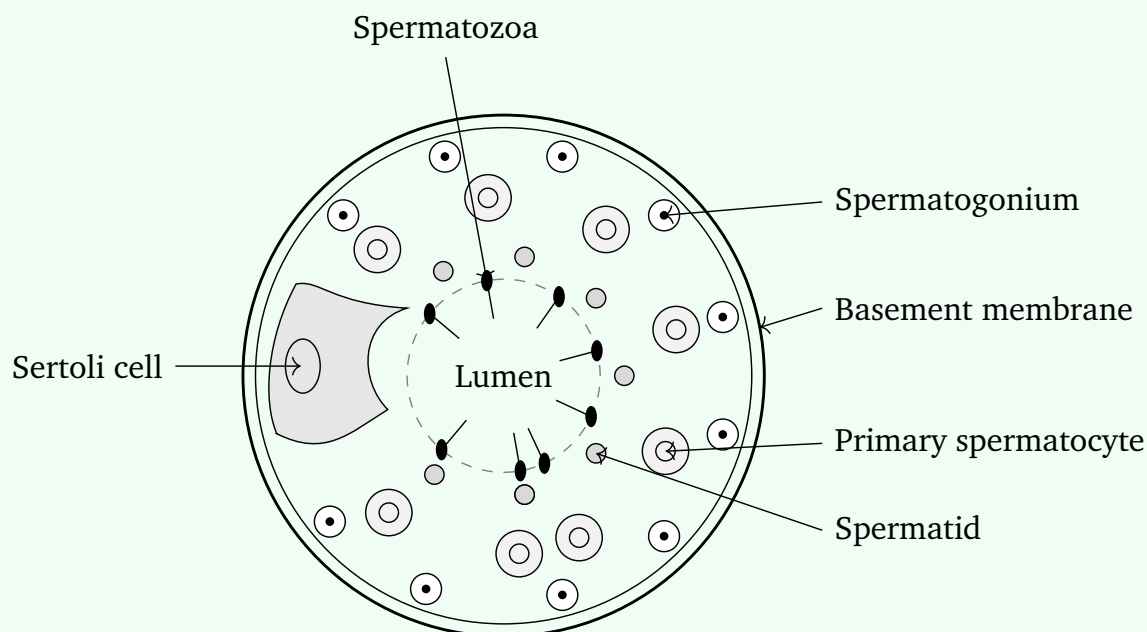
[5 marks]

Solution:

Concept:

- Seminiferous tubules are the sites of spermatogenesis in the testes. Their germinal epithelium contains male germ cells and supporting Sertoli cells; spermatozoa are released into the lumen.
- At puberty, hypothalamic gonadotropin-releasing hormone (GnRH) stimulates the anterior pituitary to release luteinising hormone (LH) and follicle-stimulating hormone (FSH).
- LH stimulates interstitial Leydig cells to secrete androgens, while FSH acts on Sertoli cells. These hormonal actions support sperm formation and spermiogenesis.

Step 1: (i) Labelled cross-section of a seminiferous tubule The diagram shows the basement membrane, spermatogonia near the periphery, primary spermatocytes farther inward, spermatids near the lumen, spermatozoa projecting into the lumen and a supporting Sertoli cell. Germ cells become progressively more differentiated as they move towards the lumen. Leydig cells lie in the interstitial tissue outside the tubule; they are distinct from the Sertoli cells inside its epithelium.



Cross-section of a human seminiferous tubule (schematic)

Step 2: (ii) Initiation of hormonal control at puberty At puberty, secretion of GnRH by the hypothalamus increases. GnRH acts on the anterior pituitary and stimulates secretion of the two gonadotropins, LH and FSH. Thus, the brain and pituitary initiate and coordinate the hormonal stimulation of sperm production in the testis.

Step 3: LH stimulates androgen production LH acts on the Leydig cells situated between the seminiferous tubules and stimulates the synthesis and secretion of androgens, chiefly testosterone. These androgens stimulate the process of spermatogenesis within the seminiferous tubules. LH therefore supports sperm formation indirectly through the hormone produced by Leydig cells.

Step 4: FSH acts on Sertoli cells FSH acts on the Sertoli cells of the seminiferous tubules and stimulates secretion of factors that help spermiogenesis, the transformation of spermatids into spermatozoa. Sertoli cells also nourish and support the developing germ cells. The coordinated action of FSH on Sertoli cells and LH-dependent androgen secretion maintains sperm development; FSH does not act by stimulating Leydig cells.

Step 5: Conclusion The seminiferous tubule contains developing germ cells and Sertoli cells around a central lumen. Hormonal regulation follows the sequence: hypothalamic GnRH stimulates pituitary LH and FSH; LH stimulates Leydig-cell androgen secretion, while FSH stimulates Sertoli-cell factors that help spermiogenesis.

Quick Tip to Solve: Remember the target cells: LH acts on Leydig cells; FSH acts on Sertoli cells. Place spermatogonia at the outer wall and spermatozoa towards the lumen.

33(a). (i) Absence of lactose in the culture medium affects the expression of lac operon in *E. coli*. Why and how ? Explain.

(ii) Write any two ways in which the gene expression is regulated in eukaryotes.

[5 marks]

Solution:

Concept:

- The lac operon is an inducible unit of gene regulation in bacteria: its structural genes are transcribed together under the control of a promoter and an operator.
- The regulatory gene *i* produces a repressor. Lactose acts as the inducer in the standard lac-operon model, allowing expression when its metabolism is required.
- Eukaryotic gene expression can be controlled at transcription and at subsequent processing, transport or translation of RNA.

Step 1: (i) Explain why absence of lactose switches off expression The structural genes *z*, *y* and *a* code respectively for β -galactosidase, permease and transacetylase. These proteins participate in lactose metabolism. When lactose is absent, the cell does not need to produce large quantities of the proteins of this pathway. The operon is therefore normally maintained in its switched-off state.

Step 2: (i) Explain the molecular mechanism The *i* gene produces the repressor constitutively. In the absence of the inducer, this repressor remains active and binds to the operator next to the promoter. The bound repressor prevents RNA polymerase from effectively transcribing the structural genes. Consequently, the polycistronic mRNA for *z*, *y* and *a* is not produced at an appreciable level, and synthesis of their enzyme products is suppressed. Thus, absence of lactose affects expression through repression of transcription, rather than through deletion or alteration of the structural genes. Normally, when lactose is available, the inducer binds to and inactivates the repressor, freeing the operator; this inactivation does not occur when lactose is absent.

Step 3: (ii) State two levels of regulation in eukaryotes First, gene expression can be regulated at the transcriptional level by controlling the formation of a primary RNA transcript from DNA. Regulatory proteins can determine whether and how efficiently a particular gene is transcribed. Second, it can be regulated at the processing level by controlling splicing and processing of the primary transcript to form mature mRNA. Changes at either level change the availability of an appropriate mRNA for protein synthesis.

Step 4: Conclusion In the absence of lactose, active repressor binds the operator and represses transcription of the lac structural genes. Two eukaryotic control levels are transcription of the primary transcript and processing of that transcript.

Quick Tip to Solve: Follow the causal chain: no inducer, active repressor, occupied operator, suppressed structural-gene transcription.

- 33(b).** (i) By taking two suitable traits in a pea plant, work out a dihybrid cross up to F_2 generation.
 (ii) State the Mendel's law derived from such a cross only. [5 marks]

Solution:

Concept:

- A dihybrid cross follows inheritance of two contrasting pairs of traits simultaneously. Use seed shape and seed colour in pea: round R is dominant over wrinkled r , and yellow Y is dominant over green y .
- Pure parents are homozygous. Gametes receive one allele of each gene, and independent assortment produces four equally frequent gamete types from the dihybrid $RrYy$.

Step 1: (i) Cross the pure parents to obtain the first filial generation Take a pure round, yellow-seeded pea plant and a pure wrinkled, green-seeded pea plant. The parental cross and gametes are

$$P : RRY Y (round\ yellow) \times rryy (wrinkled\ green),$$

$$\text{Gametes} : RY \text{ and } ry,$$

$$F_1 : RrYy \text{ (all round yellow).}$$

Each offspring receives R and Y from one parent and r and y from the other. Dominance makes all the heterozygous offspring round and yellow.

Step 2: (i) Self the dihybrid to obtain the second filial generation Self-pollinate the first filial plants: $RrYy \times RrYy$. Each produces RY , Ry , rY and ry gametes in equal proportions. Their combinations are shown in the Punnett square:

	RY	Ry	rY	ry
RY	$RRYY$	$RRYy$	$RrYY$	$RrYy$
Ry	$RRYy$	$RRyy$	$RrYy$	$Rryy$
rY	$RrYY$	$RrYy$	$rrYY$	$rrYy$
ry	$RrYy$	$Rryy$	$rrYy$	$rryy$

Of the sixteen equally likely combinations, nine are $R_Y_$, giving round yellow seeds; three are R_yy , giving round green seeds; three are $rrY_$, giving wrinkled yellow seeds; and one is $rryy$, giving wrinkled green seeds. The underscore denotes either allele at that position. Thus, the phenotypic ratio in F_2 is 9 : 3 : 3 : 1. Round green and wrinkled yellow are new combinations of the parental traits.

Step 3: (ii) State the law derived from the dihybrid cross Mendel's law of independent assortment states that, when two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of segregation of the other pair. Thus, inheritance of round or wrinkled seed shape does not determine inheritance of yellow or green seed colour in this cross. The four equally frequent gametes from the dihybrid account for the characteristic second-filial phenotypic ratio.

Step 4: Conclusion The cross $RRYY \times rryy$ gives all $RrYy$ round yellow plants in F_1 ; selfing gives the F_2 ratio 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green. It demonstrates the law of independent assortment.

Quick Tip to Solve: Write all four gametes from each dihybrid before filling the square; classify phenotypes by dominant alleles present.